UCRL- 96223
PREPRINT

Intercombination Lines of the Zinc Isoelectronic Sequence for Z = 50-70

E. Hinnov, P. Beiersdorfer, R. Bell, J. Stevens,
S. Suckewer, S. von Goeler, A. Wouters
Princeton University, Princeton, New Jersey
D. Dietrich, M. Gerassimenko, E. Silver
Lawrence Livermore National Laboratory

This paper was prepared for submittal to the
Journal of the Optical Society of America B

February 1987

Lawrence Livermore National Laboratory

DISCLAIMER

Intercombination Lines of the Zinc Isoelectronic Sequence for Z = 50-70

E. Hinnov, P. Beiersdorfer, R. Bell, J. Stevens,
S. Suckewer, S. von Goeler, A. Wouters
Princeton University, Plasma Physics Laboratory
Princeton, New Jersey 08544

D. Dietrich, M. Gerassimenko, E. Silver,
University of California, Lawrence Livermore National Laboratory
Livermore, California 94550

The intercombination lines of the zinc sequence corresponding to the transition $4s4p\ ^3P_1 \rightarrow 4s^2\ ^1S_0$ have been observed for xenon, lanthanum, neodymium, europium, gadolinium and ytterbium in the PLT tokamak discharges.

In one of the last experiments conducted on the Princeton Large Torus (PLT) tokamak, a number of elements in the rare earths group were introduced into the discharge, and their spectra were observed with a variety of spectroscopic instrumentation. While a large number of spectra containing a multitude of lines were observed, their analysis will take a considerable time. However, in all the observed spectra the zinc and copperlike resonance lines were prominent. Their wavelengths are at least approximately in agreement with observations by Reader and Luther[1] and Acquista and Reader[2] in laser-produced plasmas. In addition to these, the zinc sequence intercombination lines, which would not be observable in the high-density short-duration laser-produced plasmas, were quite substantial and they are the subject of the present paper.

In these experiments the electron temperature of the ohmically-heated plasma (~ 2 kev) was raised by adding about 0.6 MW of radio frequency power near the lower hybrid frequency[3] resulting in a fairly sharply peaked radial temperature profile with peak values 4.5-6.0 keV. The electron density profile was considerably broader with peak values $1\text{-}2 \times 10^{13}$ cm^{-3}. The rf pulse lasted for about 200 msec, and about 50 msec after its start the element in question was introduced by means of the laser-ablation technique.

The lines in question were observed mostly by means of a Spex Industries bichromator. The wavelength accuracy, checked by observing nearby iron and carbon lines that are intrinsic in the plasma, is about ± 0.2 Å or better. The lines were identified by their time behavior relative to the resonance line of the same ion species. Their intensities were of the order of 0.1 × the corresponding resonance line, but no systematic variation could be established. Some of the lines were also observed with a grazing incidence polychromator, with the improved wavelength accuracy of about ± 0.1 Å.

Xenon was puffed into some of the discharges and its line established by analogous means.

The results are given in Table I, and shown graphically in Fig. 1. The curve in the figure is drawn in this fashion, because it is known to go up at lower Z - the measured transitions are 481.0 Å for molybdenum[5,6], 561.4 Å for zirconium[6].

The transition could have been followed to considerably higher values of Z under the experimental conditions, but for the lack of priorities in the limited times available. We should also like to point out that for the two heavier elements most likely to have been used, tungsten and gold, the extrapolated wavelengths are very close to the berylliumlike resonance lines of iron (Fe XXIII, 132.92 Å) and of nickel (Ni XXV, 117.99 Å) respectively.

The support of H.P. Furth and S. Bernabei is gratefully acknowledged. We also wish to thank the PLT crew for the technical assistance. One of us (P.B.) has been supported by the Fannie and John Hertz Foundation.

This work has been supported by U.S. DOE Contract No. DE-AC02-76-CHO-3073. This work also was supported in part under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract #W-7405-ENG-48.

Table I

Wavelength of the 4s4p $^3P_1 \rightarrow 4s^2\ ^1S_0$ intercombination lines of the zinc sequence.

Spectrum	Wavelength (Å)	Comments
Ag XVIII	352.3 ± 0.2	previous result*
Sn XXI	<302.0>	interpolated
Xe XXV	252.5 ± 0.2	present measurement
La XXVIII	224.3 ± 0.1	present measurement
Nd XXXI	201.3 ± 0.1	present measurement
Eu XXXIV	182.2 ± 0.2	present measurement (CVI interference)
Gd XXXV	176.6 ± 0.2	present measurement
Ho XXXVIII	<161.3>	interpolated
Yb XLI	148.17 ± 0.1	present measurement
W XLV	<133.1>	extrapolated

*Ref. 4

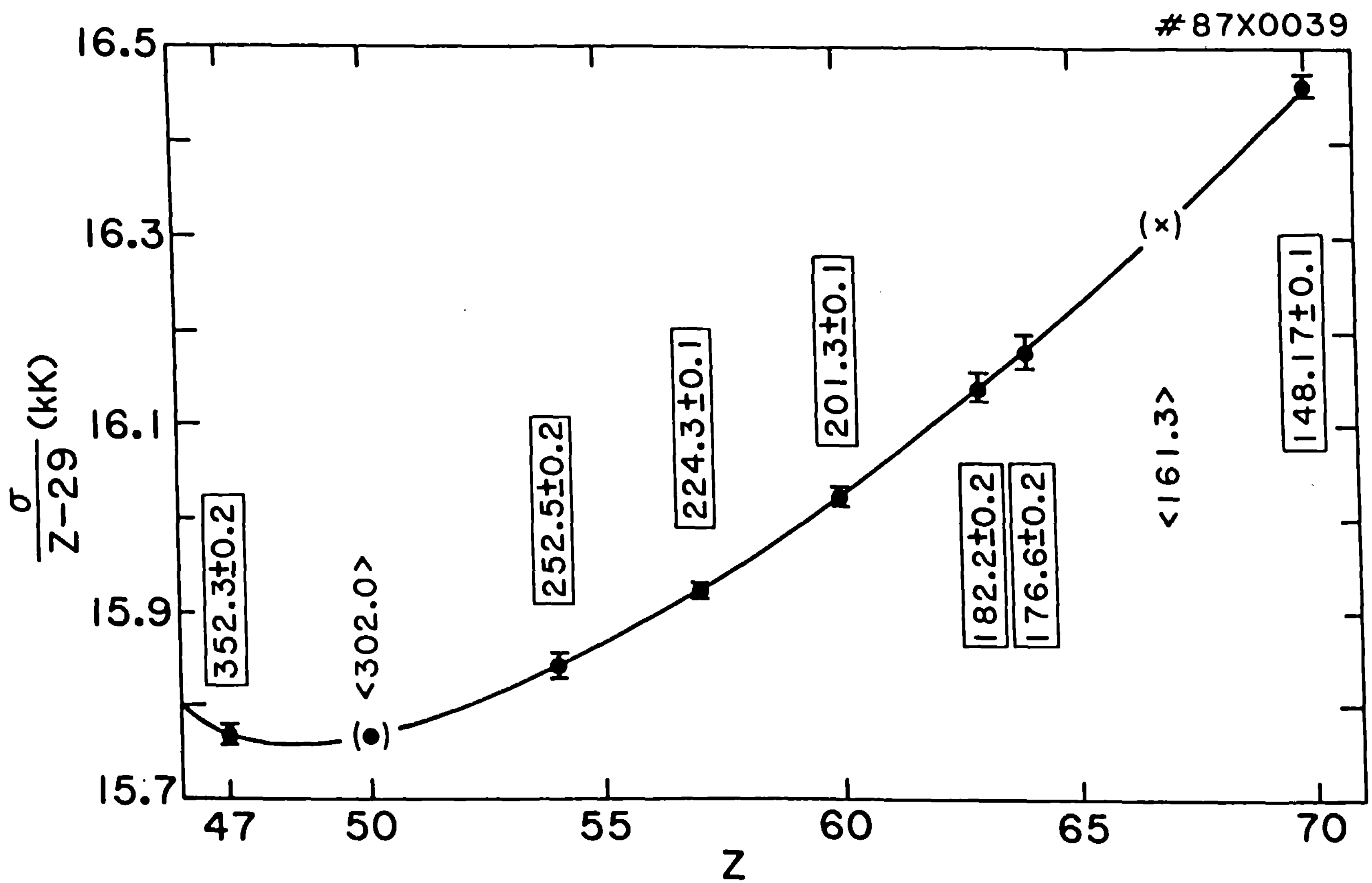

Fig. 1 Wave number per core charge for the observed transitions, vs the atomic number Z.

References

1. J. Reader and G. Luther, Physica Scripta <u>24</u> 732-737 (1981).

2. N. Acquista and J. Reader, J. Opt. Soc. Am. <u>B1</u> 649-651 (1984).

3. R.E. Bell et al., Bull. Am. Phys. Soc. <u>31</u> 1466 (1986);
S. Bernabei, R.E. Bell et al. Proc. 11th Intern. Conf. on Plasma Physics and Contr. Nucl. Fusion Res. Kyoto, Japan 1986, IAEA-CN-4/F-II-1.

4. B. Denne, E. Hinnov, S. Cohen and J. Timberlake
J. Opt. Soc. Am. <u>B2</u> 1661-1665 (1985).

5. M. Finkenthal, R.E. Bell, H.W. Moos, A.K. Bhatia, E.S. Marmar, J.L. Terry, J.E. Rice,
Phys. Lett. <u>82A</u> 123, (1981).

6. B. Denne, private communications, 1982.